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ABSTRACT

This presentation focuses on the extent to which students are handicapped when the medium of instruction in the content fields is a language other than their mother tongue. The presentation has three parts. First, the International Association for the Evaluation of Educational Achievement (IEA) research literature regarding the impact of language factors on science achievement is reviewed. Second, information from the National Assessment of Educational Achievement in Botswana is used to describe the magnitude of the problem in many developing nations. Third, major causes of science achievement for linguistically handicapped students are examined by reference to a survey of science achievements of international students at a Stockholm (Sweden) upper-secondary school. The main conclusion reached is that students are severely handicapped when the medium of instruction in the content fields of schooling is a language other than their mother tongue. Attention is drawn to the necessity of educational aid agencies taking into account the entire culture-learning context in view of the finding that the mere equalization of educational resources across schools/nations is not enough to achieve parity of results. (HM)

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SCIENCE ACHIEVEMENT WHEN THE INSTRUCTIONAL MEDIUM IS THE STUDENT'S SECOND LANGUAGE

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Abstract

Three arguments are invoked in order to account for the modest achievement performances of science students in nations where the instructional medium in science is the student's second language. These are referred to as the "early reading", the "cultural base", and the "cognitive style" arguments respectively. The obverse of the cognitive style argument is the psychic unity thesis - a position which constitutes the basis of education resource distribution within nations and aid-to-education policies between nations. Scattered evidence of the high inference variety is presented from the data archive at the Institute of International Education, University of Stockholm, supportative of the three arguments. The main conclusion reached is that students are severely handicapped when the medium of instruction in the content fields of schooling is a language other than their mother tongue. Attention, too, is drawn to the necessity of educational aid agencies taking into account the entire culture-learning context in view of the finding that the mere equalization of educational resources across schools/nations is not enough to achieve parity of results.

The data presented in this paper were gathered under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) and the Institute of International Education (IIE), University of Stockholm. Data for the Report of the National Commission on Education in Botswana were gathered with the support of the Ford Foundation, the Swedish International Development Agency, and the Government of Botswana. Data on the English language science program for foreign students at one of Stockholm's upper secondary schools was gathered under the auspices of the Research Centre, City of Stockholm Board of Education. Most other data were from the IEA "Six-Subject Survey" available in the IEA data bank. The authors wish to acknowledge the contribution, interest and support of Torsten Husén of IIE; and wish to thank Benjamin S. Bloom, University of Chicago for a critical appraisal of an earlier draft of this paper which was presented at the Annual Meetings of the American Educational Research Association, Toronto, in March 1978. Bengt Ahnmé and Enn Sjöberg of the Research Centre, City of Stockholm Board of Education; Ulla Kann and Richard Noonan of IIE; and Lawrence Saha of the Australian National University contributed significantly to the Study. The third author acknowledges the support of the Aspen Institute Berlin during his 1976-77 Research Fellow Appointment at IIE which made the collaboration on this paper possible.

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I. Introduction

Tens of millions of the world's children attend schools where the medium of instruction in the content fields is a language other than their mother tongue. Some scattered evidence is reviewed in this paper which shows that these students may be handicapped in that the language barrier may constitute an overwhelming obstacle in understanding such important school subjects as science.

The problem is particularly acute in former colonial nations in Africa south of the Sahara, but it is still familiar enough for language minorities in some of the world's most populous nations - Bangladesh, the People's Republic of China, India, Indonesia and the Soviet Union.[1] One attempt to estimate the magnitude of the problem on a world-wide scale resulted in a total of around one quarter of a billion children who would have to study science in a second (world) language if they were to study science in secondary school at all.

Except in wealthy nations - say, where per capita incomes are above the US $1,000.00 a year mark - the fact is that few of these students would have the opportunity to study science. Language constraints would effectively bar progress in the content fields to the level where students could profit from science instruction, as well as sap motivation and aspiration. And as if this were not enough many of the world's children cannot study science because of a world-wide shortage of science teachers.

Many children, then, from minority language groups will have at least one strike against them; and many will be doubly or triply disadvantaged.

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[1] Consider, too, the several million children of guest workers in several West European nations; first generation immigrants from non-English speaking nations in North America; and the native-speaking indigenous peoples of North America.

Three arguments are presented in this paper which may account for why language and related factors handicap students who have to study science in a second language. These are referred to as: the early reading, the cultural base, and the cognitive style arguments respectively. A fourth argument is invoked which, on the face of it, runs somewhat counter to the other three and which is labelled "the psychic unity" argument. In the second place a modest and preliminary effort is made to describe the magnitude of the problem in the developing nation case. Thirdly, some scattered prima-facie evidence is culled from the data archive of the Institute of International Education, University of Stockholm, to provisionally test some hypotheses derived from the four arguments.

One important caveat. It is readily conceded that the commitment to the language-resource-factor-basis of science achievement, which we deem to be proper in this context, has necessitated our disengagement from other - perhaps complementary - points of view. Thus, additional approaches are excluded from consideration.

II. Handicapping: Four Arguments

(i) The Early Reading Argument

In most of the former French colonies in Africa the language of instruction in the early grades of school is still French rather than the vernacular (see Table 2). The same is true of the former Portuguese- and Spanish-speaking colonies. In contrast, in anglophone West Africa mother-tongue education is becoming more widespread as the instructional medium in the primary grades. Nevertheless, in practically all secondary schools south of the Sahara the language of instruction in science is the official political language of the country - usually French or English. To complicate

matters, because University-level study of linguistics and African languages in particular was negligible prior to political independence, there is evidence that teacher-training in mother-tongue education is underdeveloped (cf. Awoniyi 1976, p. 41).

In the African situation the problem may be three-fold. First, the evidence supports the thesis that learning a second language may be most sucessfully accomplished only after mother-tongue literacy has been mastered (Orata 1953, UNESCO 1953, Fox 1975, Bamgbose 1976, and Yai 1976). Second, learning to read requires oral language readiness. Third, reading is reasoning; which is, in turn, the procedural logic underlying scientific understanding. Thus, not to capitalize on the child's mother tongue oracy in the teaching of reading in the early grades, or to introduce the official language as the medium of instruction in the content fields before reading competency in the mother tongue has been firmly established, is tantamount to deliberately obstructing a child's educational progress.[2] In short, the major premise of education in most African nations is wrong. Apart from official language policies handicapping school achievement, they also impede

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[2]It is acknowledged that this generalization may be too simplistic. Fishman (1974, 1975) refers to the varigated nature of bilingual education and identifies the following important classification criteria: (i) intensity variation, (ii) goal variation, (iii) degree of ethnic diversity of the population served, and (iv) the mother tongue status of the language utilized for instructional purposes.

socioeconomic development as shown by Harvey, Marsden, and Bulcock (1972).[3]

The policy of using the students' mother tongue as the teaching medium rather than monolingual English or French or some other world language is the preferred UNESCO position (UNESCO 1953). Nevertheless, to some authorities such as Dakin (1968) the evidence is not conclusive since "the superiority of the mother tongue has not everywhere been demonstrated". Thus, for example, foreign language teachers in Canada support language immersion programs wherein children learn to read in the second official language prior to learning to read in their mother tongue (cf. Lambert and Tucker, 1971; and Tucker, Lambert, and d'Anglejan 1972).

The Canadian case may be a special one, however, as Lambert, Just and Segalowitz (1970) point out; hence, not generalizable to different socio-political contexts. Thus, it is salutory to point out as does Bamgbose (1976, p. 16) that in many developing nations education in the mother tongue

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[3]The importance of the language factor in education and its role in socio-economic development may be largely unrecognized. The Phelps-Stokes Commission's reports (1920-21 and 1924) drew attention to the central importance of language in multilingual African countries but had little impact on language policies. In reference to the reports of British Education Commissions prepared to facilitate the transfer of governmental responsibilities, Cawson (1975) writes:

> Their reports either ignored the language situation altogether or made a few routine references to improving the teaching of English. The Malawi report of 1960 gives 3½ out of 360 pages to language...the Kenya report of 1964 gives 5 paragraphs out of 531. It isolates for special study 16 problems facing Kenya; language is not one of them. The improving of English is likewise the only language matter considered in the Uganda report of 1963 in 3 pages out of 83; in the Ghana report of 1967 one page out of 160 and in the (Ashby) Nigeria report of 1960, in five lines out of eight thousand. (cited in Fox, 1975, p. 82).

But such myopia may be more prevalent than generally realized in education. To give a modest example, note the total absence of any reference to the impact of declining fertility ratios and other demographic shifts on education in the 1977 or 1978 AERA annual meetings. Note, too, the numerous sessions on educational change at the same meetings. Yet, one division of AERA has a specific mandate for examining the social context of education.

will probably be the only avenue to literacy for most of the population. Saville and Troika (1971) express the matter well:

> The use of the native language for classroom instruction allows the education of the child to continue uninterruptedly from home to school, permitting immediate progress in concept building rather than postponing development until a new language has been acquired...past methods in monolinguistic English education have often proved ineffective with children who speak other languages natively, and more and more of these children are beginning school every year. For them, learning to read in English may be frustrating if they lack oral language readiness for it.
>
> ...When a child is ready to read his native language and is not taught to do so, the school misses a valuable opportunity. A child who starts off with frustrations or failure may never catch up. A low self-image, lack of motivation, and unsatisfactory performance are often interrelated handicaps to a child whose initial instruction is in a foreign language - indeed, to any child. These may be compounded by a low expectation of learning capacity on the part of the child himself, his parents, teachers and administrators.

The importance of reading stems from the fact that it is not a precise and distinct skill but rather a selective process, and as such an indication of the general level of the individual's thinking and reasoning processes - a thesis proposed by E.L. Thorndike (1917) over sixty years ago. More recently it has been argued that the grapho-phonic skills taught by the reading teacher, plus the continued within-class development of the child's syntactic structures and semantic codes constitute the primary verbal reasoning processes. It is the development of these strategies through the encouragement of what Goodman (1976) refers to as "risk-taking, meaning seeking, and hypothesis testing"; which involve the ability to react to what is read through checking validity, evaluating, making inferences, and drawing conclusions, which justifies R.L. Thorndike's (1973-74) claim that "reading is reasoning".

More recently the authors have examined the relationships between reading as reasoning and selected content fields of schooling (e.g., general

science - including physics, chemistry, biology, and practical work as subtest areas - and literature) while simultaneously taking into account other explanations of academic achievement (cf. Bulcock and Beebe 1976, Bulcock 1977 and Fägerlind and Beebe 1978). The findings support a language resource model of science achievement (Bulcock, Clifton and Beebe 1977) where it is hypothesized: (i) that a child's primary resources in terms of cognitive development are linguistic skills which are already inequitably distributed by the time children begin school; (ii) that the school classroom constitutes the treatment setting where these primary assets are translated into additional resources, foremost among which are reading competencies; (iii) that these competencies in "reading as reasoning" may be interpreted as important secondary resources; and (iv) that the primary and secondary assets jointly constitute the major common causes of the multiple subject-matter achievements (or tertiary resources such as science, mathematics, and languages as the object rather than the medium of instruction) of pupils in elementary and secondary schools. These hypotheses were shown to account for achievement variation in the natural sciences of nationally representative probability samples of 14 year-olds in England, Sweden, and Hindi-speaking India.

Further, since other explanations of performances in the content fields are frequently invoked - for example, socializing differences, sex differences, and thinking stage arguments - it has been shown that the language resource conversion thesis holds cross-culturally, while simultaneously taking these other explanations into account. The general conclusion was as follows:

> Though the primary and secondary resources of the students in both countries (England and India) constituted the single

> most powerful explanation of achievements in physics, chemistry, biology, and practical work, the socializing and thinking stage arguments were independently operative; and, therefore, the three arguments might be legitimately regarded as complementary rather than competing notions." (Bulcock, Clifton, and Beebe, 1977, p. 27).

It is for these reasons that it is believed that the development of early reading in the mother tongue is the key to subsequent progress in the content fields of schooling. Failure, then, to capitalize on oral language readiness in the mother tongue in the teaching of reading through insistance on use of a second language as the medium of instruction in the early grades is likely to prove counter-productive. It is believed, therefore, that linguistic imperialism is probably the most effective policy of ensuring the political and economic dominance of a region, territory, or country. Children not taught to read in the vernacular will already have one strike against them in terms of learning the content fields. They may have two strikes against them if official policies retard the dynamics of living vernacular languages in that

> ...a living dynamic culture can only be maintained through the cautious and conscientious transformation and generation of language and thought. If a culture retreats into a circle of comfortable and reinforcing language and symbolism, then it will cut itself off from the creative energies that are its life source. (Den Ouden, 1975)

In sum, then, reading is not merely a skill but an indicator of an individual's reasoning ability; hence a common cause of multiple subject-matter competencies. To retard development of mother-tongue reading is to retard development of understanding the content fields and to run the risk of undermining the dynamics of cultural development.

(ii) <u>The Cultural Base Argument</u>

In the mid-1960s the International Association for the Evaluation of Educational Achievement (IEA) conducted an international survey of mathematics achievement, the results of which were reported in two volumes edited

by Husen (1967). Improved theoretical models and a more vigorous research design was developed for the next phase of IEA research conducted in 1967-1971 known as the six-subject survey - in reading comprehension, mother-tongue literature, science, English as a foreign language, French as a foreign language, and civic education. The results of these surveys reported in some nine monographs published by IEA have, in general supported the Bloom (1969) thesis that educational systems seldom break through the ceilings imposed by the cultural constraints operative in particular nations. This thesis has been extended to infer that education alone is unlikely to prove a particularly viable mechanism of social change/reform. The cultural base argument is an attempt to explain the Bloom thesis and its more recent extension.

Language develops concomitantly with growth in the cultural base of a society. Western languages especially have undergone rapid vocabulary development in the past century in response to changing technological demands; though the changes have been uneven as between different groups of users. It seems that the ongoing codification and elaboration of these languages have had greater utility for some social classes than others, though according to Fishman (1968, p. 11) little seems to be known about these matters.

If world language systems are undergoing constant elaboration and extension, and if these developments take exponential form as in the case of the language recodification and technological development relationship, how much more necessary are parallel language developments in societies where language systems may have been less dynamic? Second-language learning may be more necessary for the users of relatively static language systems than for the users of dynamic languages.

There are several practical reasons why instruction in a second (world) language may be necessary and why at some point in the school career the mother tongue as a language of instruction may have to be abandoned. The cultural base argument is one of them. The notion is simple; namely, the cultural inventory determines the rate of change in society as well as its cultural vocabulary. The richest cultural vocabularies are found in those societies with the richest, and usually longest, literacy traditions, and with the most elaborate and highly developed technological base. To get on the inside of the cultural developments in the highly developed nations it is faster - even though a greater gamble - for the individual to learn the world language than to wait until the mother tongue has been recodified through planned vocabulary development.

Where there are multiple language groups in a country it is sometimes unrealistic in terms of available resources to provide separate schools for each mother tongue group. Similarly, the provision of suitable reading materials in each mother tongue may be difficult. Thirdly, although linguists have shown that all living languages are open, equally complex structurally, and capable of infinite lexical expansion from a limited number of phonemes; that is, all are potentially expandable into world systems, the fact is that members of minority language groups including those with lexical systems more than adequate for advanced curriculum needs - e.g., the Scandinavian group, Dutch, Flemish, etc. - will be handicapped if they are unable to communicate in a language of more universal discourse such as English or French or Russian. This is not to say that the world language needs to be the medium of instruction in the schools, only the object of instruction.

Nevertheless, if the minority language lacks an adequate vocabulary for the teaching of, say, science or more advanced mathematics it may be necessary to introduce a second language at an early stage of schooling. In such a case the recommendation of the Report of the UNESCO Meeting of Specialists, 1951 (1953) might be borne in mind:

> The transition to a second language should normally take place gradually and should be made as smooth and as psychologically harmless as possible. Thus, if the second language is completely different from the mother tongue it should be taught as a subject for some years...until such time as the child has (acquired) an adequate working knowledge of it..before it is brought into use as a full teaching medium.

It is posited, therefore, that children whose mother tongue lacks the vocabulary for studying thought forms such as science, because the cultural base of their society is underdeveloped relative to those found in technically advanced nations, will be linguistically disadvantaged compared to their peers in countries where the mother tongue is a world language. If, further, these children have to use a world language as the medium of instruction from the earliest grades of schooling, they will be doubly disadvantaged.

(iii) The Cognitive Style Argument

It is common for sociologists and anthropologists to find that the quality of thought and the cognitive styles of individuals differ as between the rich and the poor, or as between individuals in First World nations and those in the Third World (e.g., Gladwin 1970). Such findings are supportative of the thesis that distinctive styles of thought develop in some cultures which are different from those developed in markedly different cultures. By the same token, distinctive styles of thought develop under conditions of poverty which are different from those developed under conditions of affluence. If cognitive styles differ and the poor are

treated the same in school as the rich, then the schools are institutions which may penalize children for the mere fact that they are poor. Similarly, to transfer educational institutions from the indigenous culture to a different culture under the assumption that what is appropriate for one may be similarly functional for the other may be a form of educational imperialism.

Oracy is achieved "naturally" in all human societies. Further, infants the world over follow a similar acquisition strategy in learning their mother tongues - a strategy characterized by the sequential internalization of syntactic structures (Scribner and Cole, 1973). It is through the acquisition of oral language that thoughts, needs, problems, experiences and feelings can be shared; which, in turn, ensures that the user's capacity to conceptualize, remember, generalize, infer, reason, and evaluate is developed. Thus, to constrain communication is to inhibit social participation, to promote isolationism, because the early language of the child as Davis (1940) has poignantly pointed out is the vital force linking the society and self, the culture and the personality. The link, then, between the inner-man and external society, between the individual and social change is language.

Literacy on the other hand is usually not conceived of as occurring "naturally", probably because of its cultural variability both within and between nations. Given that oral language is unsuited for preserving language over time or transmitting language through space it may well be as Goodman (1976) points out that the acquisition of literacy is as "natural" as is that of oracy in societies where these preservation and transmission functions of language are cultural imperatives. In societies where the level of complexity necessitates the emergence of a written language

> ...children begin acquisition of literacy in much the same way (as they acquire oral language). They sort out from the environment the print and its relationship to everything else in that environment. They will be most aware of the print that has functions which overlap those of oral language such as that which names and identifies - logos and brand names on cars, or their own names - that which controls - signs for stop, exit, no parking. If they have a lot of experience with books and newspapers, they may become aware of more abstract functions of providing information or entertainment through literature.

What if the culture is impoverished in terms of the availability of the printed word? Can one assume that there will be a concomitant absence of a cultural imperative for literacy? And where the functional need for literacy is absent will there not be a lack of opportunity to acquire literacy?

Because oral language use tends to be restricted to the situational context in which it is being used, an advantage of written language is that it can be used even when one is not in a face-to-face situation with others. Thus, it is especially appropriate for the expression of more complex and abstract ideas than oral language - which is not to say that oral discussion cannot be abstract. It may help to account, however, for the differences in cognitive style as between cultures with a tradition of literacy covering numerous generations, and cultures where such a tradition is new or newly emergent.

Effectively the opportunities for individuals from newly literate societies to get on the inside of thought forms highly dependent on the incremental development of theory will be restricted. Even when the necessity for extending the oral tradition through the acquisition and development of a literate one becomes apparent, the emergence of mass literacy is usually preceded by a stage of development in which only a relatively small corps of literate people are required to serve day-to-day purposes.

Young people who have to bridge the gap between an oral tradition and a literate one in newly literate societies may effectively be attempting a quantum leap from one style of thought to another without the advantage of the existence of supportative institutions indigenous to the culture. Just as hearing-impaired persons are cut-off from the sound of the language, individuals from newly literate societies are cut-off from the cultural base supportative of the linkages between the oral and literate traditions. Attempts at understanding science for such culturally disadvantaged individuals may be as difficult as it is for the hearing-impaired person to learn how to speak.

(iv) The Psychic Unity Argument

The psychic-unity argument is effectively the obverse of the cognitive style argument. It is referred to over-and-above the cognitive style differences position because we wish to draw attention to the educational policy implications of the culture-cognition controversy. Saha and Noonan (1977) have identified these two opposing positions as follows:

> The first (the cognitive side) is based on the belief in the "psychic unity of mankind" originally developed by Boaz and more recently elaborated by Horton and others. According to this position the differing knowledge content and systems represent no more than different cultural conventions with no differences in actual cognitive processes.
>
> However, the alternate position holds that differences in substantive knowledge and problem-solving abilities represent more profound and fundamental differences in logic and other thought processes.

The resolution of the dilemma has profound implications for educational practice. If the "psychic unity" position is supported; namely, that different knowledge systems are merely different cultural conventions and resources, with no differences in cognitive processes, the solution

lies in upgrading school systems. The resultant equalization of resources across schools, and uniformity of structure, will be automatically followed by the achievement of greater parity of results. By-and-large these policies are the one's governing the resource allocation and aid-to-education policies both within nations by government departments and between countries by international aid agencies. Thus, according to World Bank spokesmen, Alexander and Simmons (1974), if the assumptions underlying the psychic-unity position are unacceptable, then the burden of proof rests with those who reject them. For the adherents of psychic unity, then, the problem is largely one of identifying which manipulable resources are the most effective sources of educational efficiency as described, for example, in the World Bank's "Education Sector Working Paper" (1974).

If, however, differences are due to the very process of cognitive achievement being different for the members of different cultural groups, then educational policy will have to take into account the entire culture-learning context. The questions of how educational systems break through the ceilings imposed by cultural constraints is a far more complex one than the one of how to equalize the distribution of educational resources. It is contended that language development is perhaps the most central and pervasive force in terms of the ecology of education; and, more narrowly, in terms of understanding science.

Recent research by the authors using IEA data sets from England and India supports the thesis that the relationship between stage of thinking and subject matter achievements in the sciences (physics, chemistry and biology) for 14 year-old boys is different for different cultural groups.

The very process of science achievement was found to be different for Hindi-speaking 14 year-olds than it was for English 14 year-olds, such that students from the industrial nation were found to be disproportionately favourably advantaged in terms of achievement in science. On the basis of this preliminary analysis of nationally representative samples of junior secondary school students the authors (Bulcock et. al., 1977b) reject the psychic-unity-of-mankind thesis in favour of the cultural differences position.

III. Problem Magnitude

Two categories of information are relevant to the problem of science achievement when the instructional medium is the student's second language; namely, information describing the extent of the problem, and information explaining why the problem is more acute for some individuals than others; some nations than others. Knowledge that the problem is more acute for youth in less developed nations than in more advanced nations; for females than for males; for multi-lingual nations than uni-lingual nations, describes the problem. Such information, however, provides little in the way of guiding policy actions designed to ameliorate the problem. Information informing social policy relates to the underlying causes of between-nation variability in science achievement; but little data suitable for the kind of analysis necessary in order to identify causal linkages is available; and what is available tends to be scattered.

An examination of the problem magnitude is restricted to African nations. This is because the relevant data on linguistic minorities in some of the world's most populous nations; e.g., the People's Republic of China

and India, are not readily available. In terms of the four arguments, some six variables seem to provide prima-facie evidence of the problem magnitude; namely, official language policy, literacy rates, percent of population in school, the population per teacher, the degree of language homogeneity, and the language of instruction in the early grades.

All African nations South of the Sahara are multi-lingual. Among these nations there seems to be widespread agreement that an official Western (political) language is a necessity if the nation is to participate in the wider culture and economy of the world. For the former colonies, the decision as to which world language should be the official one is straightforward. They use the language of the former colonists of their countries which in most instances is either French or English as shown in

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Table 1 About Here

Table 1. The question arises as to when the official language should be introduced into the educational system. As far as can be ascertained from library sources the problem has been resolved by the African nations as illustrated in Table 2.

Table 2 About Here

Other things being equal, it is hypothesized on the basis of the early reading argument that science achievement will be greater in nations where students learn to read in the mother tongue prior to use of the official language as the medium of instruction. It is seldom, however, that other things are equal, which means that in order to test this and similar hypotheses controls have to be placed on potentially confounding factors:

e.g., literacy level, percent of population in school, population per teacher, and the language homogeneity as in Table 3. For comparative

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Table 3 About Here

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purposes parallel data has been provided for four socio-politically different European nations - Hungary, Sweden, U.K., and U.S.S.R.

IV. Hypothesis Testing

(i) The Unilingual Model

If one is willing to accept an oversimplified conceptual model as a heuristic device; and if for the sake of parsimony at this stage one accepts the psychic unity thesis;[4] then, a macro-model of national-level achievement in science might be represented as in Figure 1. In this con-

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Figure 1 About Here

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ceptual scheme the literary level of a nation is a function of its cultural base, including the adequacy of the vernacular vocabulary, the degree of language homogeneity (See Table 3, Col. IV), and educational resources; and the national level of socioeconomic development in which urbanization and commutative (trade and monetary exchange) developments may constitute key indicators. All three factors are assumed to be independently operative as predictors of scientific attainment. Since all Figure 1 relationships are positive it is hypothesized that in nations where (a) the levels of vocabulary development of the national language lacks congruence with the

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[4] Because the psychic unity of mankind position is effectively the obverse of the cognitive style argument, acceptance of this simplifying assumption - namely, that cognitive factors are constants - renders cognitive style a redundant factor.

language of scientific thought; where (b) the educational resources (teachers, facilities, aids and materials) are restricted; where (c) the patterns of human settlement, for example, are primarily pastoral/agricultural; and where (d) business institutions - trade and commerce for example - are underdeveloped, the formation of human capital in terms of numeracy and literacy will lack the imperative that is found in more "advanced" nations; and, further, all of these factors in turn will operate to retard the generic evolution of scientific thought.

IEA research provides tentative support for most of these relationships. Thus, Thorndike (1973, pp. 128-129) shows that mean reading comprehension scores for developing countries were one to two standard deviations below those of developed nations, which provides prima facie support for the relationship in the first (LIT) segment of the basic unilingual model. Bulcock (1977) and Bulcock, Clifton and Beebe (1977) have demonstrated the magnitude of the $P_{sc,LIT}$ (LIT-SC) relationship in three nations (England, India, and Sweden). Thorndike (1973, p. 169) has also noted that the prediction of science is mediated "almost entirely" by reading comprehension which at the macro-level translates into the notion that exogenous predictors of scientific attainment are mediated by literacy levels. Finally, Comber and Keeves (1973, p. 120) in their discussion of comparative test score performances in biology, earth science and chemistry, physics, and practical work in science for 10 year-olds, 14 year-olds, and terminal upper-secondary students in nineteen countries note that "in general, the mean scores for developing countries are nearly a standard deviation...below the mean score for the developed countries."

(ii) The Bilingual Model

If science instruction is in a language other than the students' mother tongue the conceptual model depicted in Figure 1 will be seriously misspecified in that a key determinant of science achievement - fluency in the language of instruction - will have been omitted. At a national-level of data aggregation this variable may be represented by the level of bilingualism (vernacular and official language) as in Figure 2. Bilingual

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Figure 2 About Here

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quality (BQ) is shown as a variable which completely mediates all the effects of CBASE, SED, and LIT on SC. It is seen as qualitative rather than quantitative in that it is defined as the proportion of the population fluent enough in the official language that it can be used to develop the logic of propositions and the operations of combinations and proportions; that is, where the second (world) language can be used for thinking in the hypothetico-deductive mode as demanded by the scientific forms.

The BQ factor accounts for why students from developing nations who have to master a second language as the medium of instruction in the content fields are doubly disadvantaged. Like students in Chile and India whose performances fall below their peers in developing nations (cf. Table 6.3, in Comber and Keeves, 1973) they are handicapped in terms of CBASE, SED, and LIT, all of which, in turn, affect BQ. Regardless of all other considerations, if bilingual fluency in the language of instruction is not achieved - and, further, it has to be achieved to the level that makes hypothetico-deductive thought possible - scientific understanding will be denied.

The question arises as to whether national-level scientific attainment is possible under the conditions imposed by the basic bilingual model. Certainly no nation comes readily to mind. While it is true that scientists in minority language nations such as Sweden and Denmark write their monographs in English, it is still important to note that in these countries the language of instruction in science through to graduate school is Swedish and Danish, even though at the university level text books may be in English and the cryptic language of computing is largely technical English.

While a multi-lingual nation may produce a few scientific "stars", this is not the same as developing the degree of national-level bilingualism necessary in order for the nation to enter a scientific era. Assuming what seems impossible, it would still be the case that where the linguistic gap between the mother tongue and the official language is pronounced - as, say, between Tswana and English for the people of Botswana - the BQ factor will prove a formidable language barrier.

Modest evidence for assessing the magnitude of the constraints of bilingual education is available from a survey of primary and secondary education in Botswana (Husén, 1977). Consider the science achievement of Botswana secondary school students compared to 10 year-olds in India, Chile, and England respectively, as presented in Table 4 It is shown that form III

Table 4 About Here

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students in Botswana government schools achieve at the same level as English 10 year-olds. Form V students scored a standard deviation higher; while form III students performed at the same level as 10 year-olds in India and

Chile. But form III students in Botswana are between 17 and 18 years old, and form V students are 19 to 20 year-olds. In other words, the findings are congruent with the bilingual thesis since it may be plausible to assume that the necessity of studying science in a second language accounts for the disappointing science achievements of Botswana secondary school students even compared to the achievements of students from other Third World nations.

More interesting comparisons between Botswana students and 14 year-olds in India, Chile and England are made in Table 5. In keeping with hypotheses derived from the Figure 2 conceptual model it is noted that

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Table 5 About Here

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students in the developed nation, England, are more advanced in science than in the developing nations. Similarly students from developing nations who study science in their mother tongue are more advanced than students in Botswana who have to study science in a second language. Even the elite survivors of the highly competitive, examination-ridden, secondary school system in Botswana - the form V pre-university students aged 19 to 20 year-old - perform at about the same level as typical 14 year-olds in England.

(iii) The Extended Bilingual Model

What if the thought processes differ in different cultures? If the cognitive style argument is incorporated into the basic model of bilingual education as in Figure 3 it is noted that it operates to extend the explanation of bilingual quality (BQ) but that its effects on science achievement are still completely mediated by BQ. Further, the greater the

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Figure 3 about here

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cognitive style difference between the student's indigenous culture and, say, that of educated "Western man" - hence, the greater the linguistic gap between the vernacular and world languages - the greater the constraints on BQ. Alternatively, the hypothesis reads: the less the cognitive style difference the greater the opportunity to achieve the quality of second language fluency necessary to get on the inside of scientific thought. Similarly, the less adequate the cultural base and the level of socioeconomic development, the greater the apparent differences in cognitive style, which in turn will operate to constrain the acquisition of basic literacy with its debilitating educational consequences.

In presenting the psychic unity argument attention was drawn to the thesis that if it is not accepted the solution to improving the effectiveness of schooling will lie not with the equalization of resources but rather with change in the entire culture-learning context. The argument presented posits that the most pervasive aspect of this context may be the linguistic; hence, the UNESCO (1953) position is endorsed, as is the language project policy of the Ford Foundation (Fox, 1975).

Only indirect evidence for the bilingual model extension can be provided in this paper. If the obverse of the cognitive style position is held; namely, that there are no cultural differences in cognitive processes, then the solution to the differences in achievement as between First- and Third-World nations lies in upgrading school systems. If, then, linguistically handicapped students are provided with qualitatively superior learning environments and equal educational resources to those students not so handicapped, then the achievement gap should be reduced, if not closed.

In their study of the International science program introduced in 1973 at an upper-secondary school in Stockholm, Fägerlind and Beebe (1978) identify students who are studying science in their second language (English), but who are not only in a resource rich environment but also from highly privileged homes - their families for the most part being members of Stockholm's exclusive international community. These conditions seem ideal ones in which tc test the psychic unity thesis; namely, that whatever cultural/material/linguistic differences existed would be compensated for by the effective distribution and utilization of educational resources. The English language program was designed to follow the Swedish curriculum. Despite the screening of students the diversity in terms of nationality, mother tongue, and previous schooling was still considerable. To compensate for such diversity the International science program was individualized to a much greater extent than was possible in the parallel Swedish upper-secondary school program.

The authors' report on the "International Secondary School Science Program" made comparisons between three groups: the Swedish students on the "regular" science program, International science program students whose home language was English, and International science program students whose mother tongue was a language other than English. The self concepts of International students and their ambitions were about the same as those of the Swedish students. The evidence suggested that of the three groups the home language other than English group were the most ambitious.

Compare, however, the achievement test results reported in Table 6. It is noted that the "home language English" group far outscored the other

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Table 6 about here

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international science students who were studying the curriculum in a language (English) which was not their mother tongue. In reading comprehension the average score for the mother tongue English group was 44 per cent compared to 23 per cent for the "other" International students; and in science achievement the differences were 29 per cent compared to 17 per cent respectively. Because the Swedish students out-scored both groups of international students in reading and science; because the correlation coefficients between reading and science achievement for both International and Swedish students were about the same (0.432 and 0.457 respectively); and because the International students whose mother tongue was English outscored International students whose home language was not English in reading and science, those students who read well in the language of instruction had the greatest advantage in science achievement, and those students who studied in a language which was their mother tongue had advantages over those who were studying in a second language (cf. Table 7). In general, then, support for the psychic unity thesis is lacking; though, admittedly, these tentative conclusions are of the high inference variety.

Table 7 about here

There is little doubt that the International science students were privileged in terms of both access to school and home resources. Yet, as shown in Table 6 there were large and significant differences in their

cognitive achievements. Consider the differences in three areas: word knowledge, years of schooling with English as the language of instruction, and reading comprehension. The evidence seems clear enough: those students with language resource deficits are seriously handicapped in school.

The four language factors - home language, word knowledge, reading comprehension and years of instruction in English - are indicators of language resource deficits. All were associated with science achievement such that the greater the deficit the lower the achievement. Simply boosting educational resource inputs does not seem to be sufficient. Students taught in languages which are not their mother tongues do not compete on equal terms in the content fields with students taught in their home language. Where this problem exists, educational performances will be typically constrained by the extent of the language resource deficit. Thus, if the problem is a national-level problem educational achievements in these nations are most likely going to lag seriously behind the achievements of students in linguistically homogeneous nations who are taught in their mother tongue, virtually regardless of the quality/quantity of the school environments; hence, regardless of the educational resources provided.

V. Conclusion

In this paper evidence was presented showing in effect that eight years of schooling in Chile - a developing nation - are the equivalent of four years of schooling in England; that is, it takes English children half the time that it takes Chilean children to achieve at an equivalent level in

science. In Chile the medium of instruction in the content fields of schooling is the student's mother tongue. The question was asked, therefore, whether learning science would be further constrained if the instructional medium was in a second language, and especially one which was linguistically different from that of the student's mother tongue.

The evidence presented in answer to this question seemed clear enough. It was shown, for example, that Botswana students required about twelve years of schooling to achieve at the same level as those with five years of schooling in England. In other words, it takes about 2.4 years of schooling in Botswana to learn what is covered in one year in England. By the same token, what Chilean students learn in five years takes students in Botswana about seven years. The finding supports the thesis that instruction in a second language which is linguistically different from a student's mother tongue has powerful debilitating effects in terms of science achievement.

In the paper three arguments were invoked in order to explain the modest achievements of science students in those nations where the instructional medium in science is the student's second language. These were referred to as the "early reading", the "cultural base" and the "cognitive style" arguments respectively. The obverse of the cognitive style argument is the psychic unity thesis - a position which constitutes the basis of education resource distribution within nations and aid-to-education policies between nations. Evidence from several international achievement/assessment sources of the high inference variety was selected from the data archive at the Institute of International Education, University of Stockholm, which proved supportative of the three arguments. The main conclusion reached was that students are severely handicapped when the medium of instruction

in the content fields of schooling is a language other than their mother tongue. In view of the failure of the psychic unity thesis to hold up to close scrutiny, attention was drawn to the necessity of educational aid agencies taking into account the entire culture-learning context in view of the finding that the mere equalization of educational resources across schools/nations is not enough to achieve parity of results.

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TABLE 1. African Nations with English or French as the Official Political Language

Political Language	
English	French
Botswana	Algeria
Gambia	Benin
Ghana	Burundi
Kenya	Cameroun
Liberia	Central African Republic
Malawi	Chad
Nigeria	Congo Republic
Rhodesia	Gabon
Sierra Leone	Guinea
Somalia	Ivory Coast
South Africa	Libya
Sudan	Madagascar
Tanzania	Mali
Uganda	Mauritania
Zambia	Morocco
	Niger
	Rwanda
	Senegal
	Togo
	Tunisia
	Upper Volta
	Zaire

Table 2. African Nations with Official Languages Either French or English Classified According to the Language of Instruction in the Early Grades of Elementary School (N = 36)

Official Language	Language of Instruction in the Early Grades	
	Vernacular Language	Official Language
English	Ghana	Somalia
	Nigeria	Sudan
	Kenya	Gambia
	Tanzania	Liberia
	Uganda	South Africa
	Sierra Leone	
	Malawi	
	Rhodesia	
	Zambia	
	Rotswana	
French	Algeria	Cameroun
	Libya	Benin
	Morocco	Ivory Coast
	Tunisia	Mali
	Guinea	Mauritania
	Burundi	Niger
	Rwanda	Senegal
		Togo
		Upper Volta
		Central African Republic
		Chad
		Congo Republic
		Gabon
		Madagascar

TABLE 3. Language of Instruction at the Secondary School Level, Literacy Rate (I), Population in School (II), Population Per Teacher (III), and Language Homogeneity* (IV), in African Nations (1973)

Language of Instruction: English					Language of Instruction: French				
Country**	I(%)	II(%)	III(%)	IV	Country**	I(%)	II(%)	III(%)	IV
Botswana (0.69)	20	39	76	Medium	Algeria (17.30)	26	45	79	High
Ethiopia (28.68)	7	10	420	Medium	Benin (3.20)	20	18	214	Medium
Gambia (0.54)	10	19	160	Medium	Burundi (3.86)	10	15	220	Low
Ghana (10.31)	25	44	58	Medium	Cameroun (6.53)	10	41	90	Low
Kenya (13.85)	25	39	73	Low	Central African Republic (2.61)	8	33	145	Medium
Lesotho (1.04)	60	51	78	High	Chad (4.12)	6	14	358	Low
Liberia (1.75)	10	26	92	Low	Congo Republic (1.39)	20	58	43	Medium
Malawi (5.18)	22	24	154	Low	Gabon (0.53)	30	67	50	Low
Nigeria (64.75)	25	20	212	Low	Guinea (4.53)	10	20	111	Low
Rhodesia (6.53)	25	40	79	Medium	Ivory Coast (5.02)	20	39	110	Low
Sierra Leone (3.11)	10	20	109	Medium	Libya (2.44)	22	60	32	High
Somalia (3.26)	5	7	380	High	Madagascar (8.27)	39	42	109	High
South Africa (26.13)	35	55	78	Low	Mali (5.84)	10	14	211	Low
Sudan (16.13)	12	20	165	Medium	Mauritania (1.32)	5	11	146	High
Tanzania (15.61)	18	21	204	Low	Morocco (17.83)	21	26	103	Medium
Uganda (11.94)	25	21	154	Low	Niger (4.73)	5	6	543	Medium
Zambia (5.14)	--	--	---	Low	Rwanda (4.29)	10	33	192	High
					Senegal (5.11)	10	27	169	Medium
					Togo (2.28)	10	37	109	Medium
					Tunisia (5.74)	32	60	67	High
					Upper Volta (6.17)	5	5	515	Medium
					Zaire (25.63)	12	46	91	Low
Hungary (10.60)	98	52	32						
Sweden (8.22)	99	80	22						
USSR (257.90)	99	66	29						
U.K. (55.93)	98	83	24						

*The Language homogeneity is based on the percent of the population in each country speaking the dominant language: High (GT 70%), Medium (41-70%), Low (11-40%).

**Population figures shown in brackets are for 1976, in millions.

TABLE 4. Science Achievements of Botswana Secondary School Students Compared to 10 Year-Old Students in India, Chile and England

Country	Population	Mean	S.D.	Sample Size
India	10 year-olds	3.1	3.3	2,677
Chile	10 year-olds	3.9	3.4	1,483
England	10 year-olds	5.5	3.5	3,576
Botswana*	Form III, Private	3.5	3.0	188
	Form III, Government	5.5	2.8	423
	Form V	8.0	2.8	316

Source: Table 25 in Husén (1977).

*The age of Form III students in Botswana falls between 17 and 18; and the age of Form V students between 19 and 20.

TABLE 5. Science Achievements of Botswana Secondary School Students Compared to 14 Year-Old Students in India, Chile and England

Country	Population	Mean	S.D.	Sample Size
India	14 year-olds	3.5	3.8	2,934
Chile	14 year-olds	5.3	4.2	1,337
England	14 year-olds	8.9	5.5	3,132
Botswana	Form III, Private	3.0	3.5	188
	Form III, Government	4.8	3.4	423
	Form V	8.5	4.0	316

Source: Table 26 in Husén (1977).

TABLE 6. Comparisons between three groups of students attending the same school, taking the same program in science, but studying in English or Swedish as the language of instruction

Variable Measured	All Students (N = 122)	Swedish (N = 68)		All International (N = 54)		International (MT English) (N = 29)		International (MT not English) (N = 25)	
	Mean	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Self Concept	--	2.76	0.54	2.97	0.45	3.01	0.38	2.93	0.54
Ambition	--	3.53	1.52	3.54	1.08	3.40	0.92	3.69	1.24
Like School	--	2.79	1.15	2.64	1.13	2.52	1.10	2.79	1.17
Reading (%)	42.5	49.22	16.16	34.07	22.43	43.72	19.36	22.88	20.75
Science (%)	42.6	57.80	13.95	23.41	14.41	28.54	14.72	17.44	11.69
Word Knowledge (%)	--	--	--	54.54	20.66	62.50	19.98	45.30	17.65
Time in Previous Science study	--	22.41	1.72	20.60	6.64	19.86	7.49	21.46	5.53
Age	17yrs 6m	17yrs 10m		17yrs 3m		--		--	
Years Instruction in English	--	--	--	--	--	9.03	2.06	7.04	3.42
Effort Index	--	--	--	--	--	6.02	3.62	5.70	4.21

TABLE 7. Correlations between language factors and science Achievement for International students only (N = 54)

Independent Variable	Dependent Variable	
	Reading Comprehension	Science
Home Language	0.468***	0.389**
Years Instruction in English	0.363**	ns
Word Knowledge	0.736***	0.482***
Student Perception of Language level of Instruction	ns	ns
Opportunity to Learn Science	0.310**	ns
Reading Comprehension	--	0.432***

** significant at the .01 level
*** significant at the .001 level
ns not significant

FIGURE 1. Basic Unilingual Model of National-Level Achievement in Science*

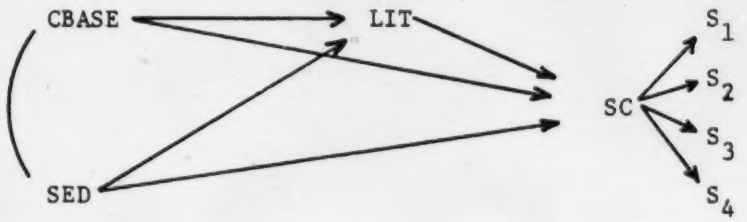


FIGURE 2. Basic Bilingual Model of National-Level Achievement in Science*

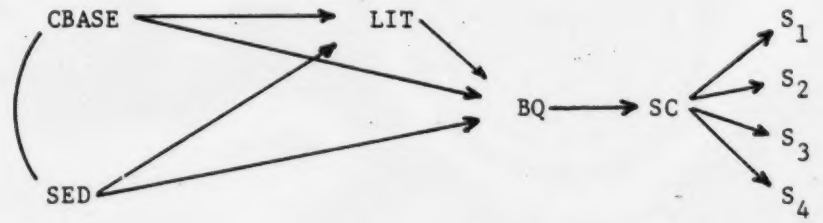
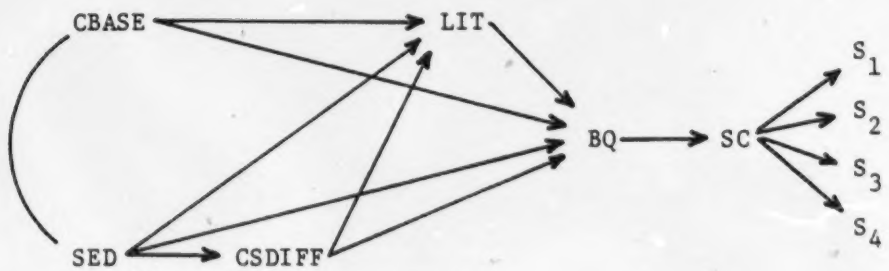


FIGURE 3. Extended Bilingual Model of National-Level Achievement in Science*



* Where: CBASE = cultural base development, especially with reference to the adequacy of vocabulary, language homogeneity, and educational resources; SED = the level of socioeconomic development with special reference to urbanization and commutation (e.g., trade, commerce, and monetary exchange); LIT = national literacy level with special reference to reading and writing competencies; BQ = bilingual quality; CSDIFF = cognitive style difference between industrial and Third-World nations; SC = science achievement; S_1 = physics; S_2 = chemistry; S_3 = biology; S_4 = technical know-how.